Effects of Weight Fraction and Soaking Temperature on Mechanical Properties of Groundnut Shell Ash Reinforced Epoxy Composite

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Abstract

The effects of weight fraction and soaking temperature on the tensile strength and modulus of elasticity of groundnut shell ash reinforced epoxy composite were studied. Particulate reinforced epoxy composite with 10%, 20%, 30%, 40% and 50% weights of groundnut shell ash were subjected to various soaking temperatures (Ambient (26°C), 40 ˚C, 60 ˚C, 80 ˚C and 100 ˚C) and were characterized for their tensile strength and modulus of elasticity.The modulus of elasticity of the groundnut shell ash and epoxy composite increased with increase in weight fraction for a particular soaking temperature while the tensile strength increased for ambient, 40˚C, 60˚C soaking temperatures and reduced for 80˚C and 100˚C soaking temperatures. The increase in modulus of elasticity is as a result of the ability of the increasing groundnut shell particles to strengthen the composite by the hydrostatic coercion in the matrix and by their hardness relative to epoxy resin.

Keywords: *Particle-reinforced composite, Tensile strength, Modulus of elasticity, Soaking temperature.*

I. INTRODUCTION

The quest for improved material properties that will withstand various stringent engineering applications has led to the development of several new materials from a combination of two or more different materials. Material properties such as high strength, modulus, stiffness, lower thermal expansion coefficient and reduced cost are vital in selection of materials for industrial applications. Bledzki and Gassan (1999) observed that there are signs that the relevance and acceptability of every engineering product will soon be determined by what types of materials have been used in manufacturing them. It is important to understand the properties, performance, cost and potential of the available composite materials. Lai *et al.*, (2003) revealed that the introduction of composite materials changed the world particularly in engineering fields. Bledzki and Gassan (1999) noted that many composites used today are at the leading edge of materials technology, with performance and costs appropriate to ultra-demanding applications, noting however that heterogeneous materials combining the best aspects of dissimilar constituents have been used by nature for millions of years. Roger (1998) reported that bio-based resources have played a major role throughout human history. Even the earliest humans learned to use these resources to make shelters, cook food, construct tools, make clothing, keep records, and produce weapons.

Aigbodion, et al., (2011) opined that composite materials have gained increasing popularity (despite their generally high cost) in high-performance products that need lightweight, yet strong enough to take harsh loading conditions in various applications such as aerospace (tails, wings, fuselages propellers), boat and scull hulls, bicycle frames and racing car bodies. They noted other uses of composite materials to include fishing rods and storage tanks. Lu and Wu (2005) observed that the new Boeing 787 Dreamliner structure including the wingsand fuselage is composed of over 50 percent composites in which polymer matrix composite is used.

Shin and Lee (2002) indicated that fibre/particle reinforced composite materials have been extensively used in transportation structures due to their high specific strength, modulus and high damping capability. If composite materials are applied to vehicles, it is expected that not only the weight of the vehicle is decreased but also noise and vibration are reduced.

Most of the developing countries are very rich in agricultural and natural fibre. Amit and Jha (2003) enumerated some bio-waste resources to include rice husk, groundnut shells, coconut shell, natural fibres from banana shell bunch, and pineapple leaves.

A. *Particulate Reinforced Polymers*

Aigbodion *et al.*, (2011) stated that in particle reinforced polymer, discrete uniformly dispersed particles of a hard brittle material are surrounded by a softer more ductile matrix. In fact, the structure resembles that of the two-phased dispersion strengthened metal alloys. Particles used for reinforcement include ceramics and glass such as small mineral particles, metal particles such as aluminum and amorphous materials, including polymer and carbon black.

The strength of the particle-reinforced polymers depends on the interfacial bond between the particles and matrix, the size of the particles (smaller size having more strengthening effect), the ability of the composite to deter crack propagation and the strength of the continuous resinous phase. Sarki *et al*, (2011) noted that in some cases coupling agents are used to give a better interfacial bonding. Other additives that may be used include plasticizers, colorants and flame retardants. The resin component in modern synthetic particulate composites transfers the stress to the reinforcing component and through this strengthening is achieved

Oksman and Clemons, (1998) have noted that for particulate-reinforced elastomers, strengthening is achieved through energy dissipation at the surface of the particles by mobile adsorption of polymer and is the result of more homogeneous stress-distribution made possible by the slippage of macromolecular chain segments over the solid surface. Polymer composite materials have generated wide interest in various engineering fields, particularly in the aerospace applications. Research is underway to develop newer composites with varied combinations of fibers and fillers so as to make them useable under different operational conditions

B. *Groundnut Shell*

Groundnut shell is a naturally occurring outer shell which provides covering for the edible groundnut seed. Sada, et al. (2013) stated that Nigeria is one of the foremost producers of groundnut in the world, producing up to about 2.699 million metric tons in 2005 and 1.55 million metric tonnes in 2008.

Groundnut Shell Ash (GSA) can be considered as important potential reinforcing material for thermoplastic composite because of its lignocelluloses characteristics. Chemically, lignocelluloses in groundnut shell particles have similar compositions as other natural re-enforcers used in thermoplastics. It is therefore, in the best interest of material development to understand and predict the tensile behaviours of Groundnut Shell Ash (GSA)

C. *Relationship Between Weight Fraction and Volume Fraction.*

The volume fraction, of particle and matrix ($\mathcal{U}_p$ and $\mathcal{U}_m$) respectively can be given as:

$$\mathcal{U}_p = \frac{Vp}{Vc} \text{ and } \mathcal{U}_m = \frac{Vm}{Vc} \quad (1)$$

where v_p, v_c and v_m refers to volume constituents of particle, composite and matrix respectively.

Similarly,

$$\mathcal{W}_P = \frac{W_P}{Wc} \text{ and } \mathcal{W}m = \frac{Wm}{Wc} \quad (2)$$

where $\mathcal{W}_P$ and $\mathcal{W}m$ are weight fractions of particle and matrix respectively, and w_p, w_c and w_m are the weight constituents of the particle, composite and matrix respectively.

A relationship between weight fraction and volume fraction can be expressed by the introduction of the density of the system and its individual components.

$$\rho_c = \rho_p \mathcal{U}_p + \rho_m \mathcal{U}_m \quad (3)$$

Recall that

$$\mathcal{W}_P = \frac{W_P}{Wc} = \frac{\rho pVp}{\rho cVc} = \left(\frac{\rho p}{\rho c}\right)\mathcal{U}p \quad (4)$$

And similarly,

$$\mathcal{W}m = \frac{Wm}{Wc} = \frac{\rho mVm}{\rho cVc} = \frac{\rho m}{\rho c}\mathcal{U}m \quad (5)$$

II. MATERIALS AND METHOD

A. *Materials*

1) *Epoxy Resin*

Epoxy resin that was used as matrix has the physical and mechanical properties shown in Table 1.

Table 1 Mechanical Properties of Epoxy Resin

Glass transition temperature (Tg)	**120 – 130 °C**
Tensile strength	85 N/mm²
Tensile Modulus	10,500 N/mm²
Elongation at break	0.8%
Flexural strength	112 N/mm²
Flexural Modulus	10,000 N/mm²
Coefficient of linear thermal expansion	34 10-6
Water absorption - 24 hours at 23°C	5-10 mg (0.06-0.068%) ISO 62 (1980)

(Source www.epoxyworktops.com)

B. Experimental Methods

1) Particulate Preparation

Groundnut shell sample was washed with water, dried, packed in a graphite crucible and fired in a control atmosphere muffle electric furnace at a temperature of 1100°C for 6hours to form carbonized groundnut shell particles (CGSp). The particle size analysis of the carbonized groundnut shell particles were carried out in accordance with ASTM-60. Two hundred grams (200g) of the carbonized groundnut shell particles was placed into a set of sieves arranged in descending order of fineness and vibrated for 15minutes which is the recommended time to achieve complete classification. The particle size used were those that passed through the 48µm sieve, (that is < 48µm).

2) Composite Preparation

The hand lay-up technique was employed in producing the composite laminate used in this study. The mould surface was cleaned with acetone and coated with a mould-releasing agent (polyvinyl alcohol, PVA) and allowed to dry. The epoxy resin was measured into a beaker and the hardener added in a ratio of 2:1. The groundnut shell ash filler in appropriate quantities were mixed with proportionate amount of epoxy resin to give 10%, 20%, 30%, 40% and 50% weight fractions of groundnut shell ash. Before casting the laminates in the mould, the mixes were vigorously stirred to ensure homogeneous dispersion of the groundnut shell ash in the epoxy resin after the additions of methyl ethyl-ketone peroxide (MEKP) and cobalt which served as catalyst and accelerator respectively.

The mould was closed and the excess resin was allowed to flow out as 'flash' by pressing in a hydraulic press. The pressure was held constant during the curing process and soaked at different temperatures of ambient (26°C), 40°C, 60°C, 80°C and 100°C for 4hours, respectively. This procedure was repeated for all samples produced with changes in the percentage ratio of mixtures or composition of the particles. Test specimens, were cut from the sheet, in accordance with ASTM standards.

3) Tensile Test

The tensile tests were performed in accordance with ASTM D638 standards (Karthikeyan1 et al., 2016) using Universal Testing Machine at a crosshead speed of 5 mm/min. Specimens for each sample were tested and the tensile strength and tensile modulus were expressed.

III. RESULTS AND DISCUSSION

Figures 1 to 5 below show that modulus of elasticity of groundnut shell ash re-enforced epoxy composite increased with increase in weight fraction for a particular soaking temperature. These results agree with the submission of Eirich, (1984); Buggy et al. (2005); Fu and Lauke, (1997), that elastic modulus of a particulate – polymer composite is generally determined by the elastic properties of its components (matrix an particles), particle loading and aspect ratio. This also agrees with Njoku, et al., (2011) who opined that since the modulus of inorganic particles is usually much higher than that of polymer matrices, the composite modulus is enhanced by adding particles to the matrix.

The figures also show that the tensile strength increased for ambient (26°C), 40˚C and 60˚C soaking temperatures but reduced for 80˚C and 100˚C of soaking temperatures.

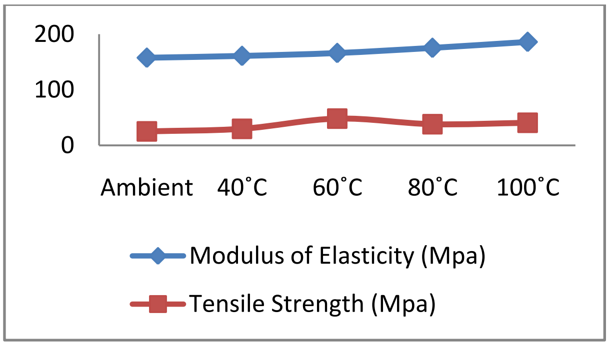

Figure 1: 10% Weight Fraction

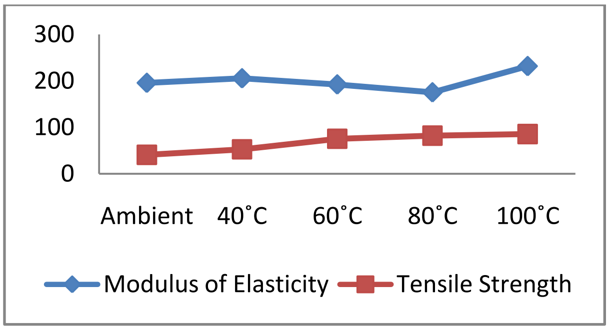

Figure 2: 20% Weight Fraction

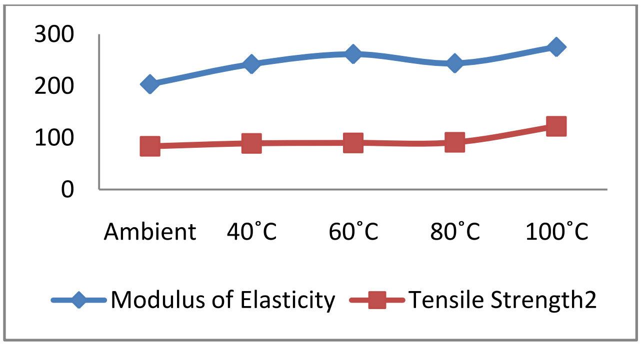

Figure 3: 30% Weight Fraction

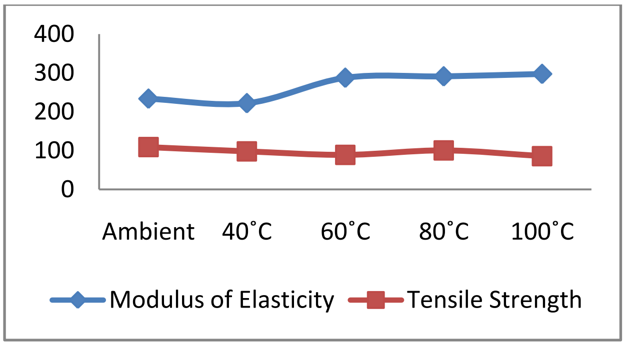

Figure 4: 40% Weight Fraction

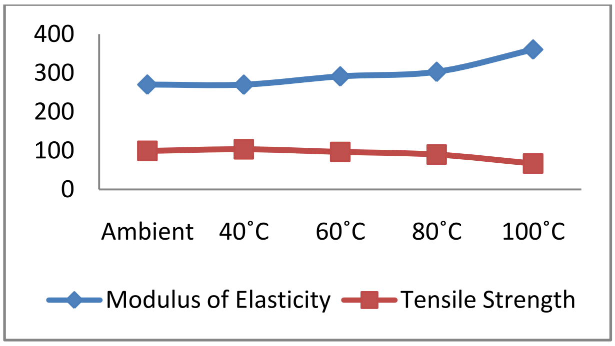

Figure 5: 50% Weight Fraction

The results equally show a gradual increase in modulus of elasticity with increase in soaking temperature for a given weight fraction of GSA in a composite.

IV. CONCLUSION

The following conclusions were made from this investigation:

1. The modulus of elasticity of the groundnut shell ash and epoxy increased with increase in weight fraction for a particular soaking temperature.

2. The tensile strength increased for ambient, 40˚C, 60˚C soaking temperatures and reduced for 80˚C and 100˚C soaking temperatures.

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